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Virtual laboratory applications in chemistry education

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Abstract

The lab applications, which were started to be applied through mid 19th century, not only provide a new point of view but also bring about a new dimension to the lessons. At early times they were used to prove theoretical knowledge but lately they turned into environments where students freely discover knowledge as an individual or in groups. The activities that have come up with the recent form of labs substantially contributed to training ideal students for constructivist approach, who research, inquire, test, seek solutions, wear scientist shoes and deeply reason about the concept of concern.

However, on the present stage of our educational system, these activities cannot be included in lessons for several reasons. At that point virtual labs emerged as an alternative solution for the problems of the instruction of applied courses. In this study the aims of using virtual labs, advantages and disadvantages of them were reviewed and some virtual lab studies in the chemistry field were introduced.

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Keywords: virtual laboratory, laboratory applications in chemistry education Introduction

1. Introduction

The science education, which has a distinct place in the educational system with its content, consists of three main disciplines named physics, chemistry and biology (Kaptan, 1996). Being one of this three main disciplines, science of chemistry contains lots of abstract concepts that causes frequent problems in conceptual instruction in the chemistry lessons. Many students have difficulties in embodying abstract concepts therefore they also have difficulties in chemistry lessons which contains so many abstract concepts (Nakhleh, 1992). For this reason it is recommended that students configure the concepts of chemistry lessons by their own. The places where students can learn and configure his or her own scientific knowledge are laboratories. Laboratory activities which are integral components of chemistry lessons enables students to build up their own experience with concrete materials (Ayas and others, 2005; Taşdelen, 2004). Beach and Stone (1988) express that the most efficient way of chemistry education is through laboratories and they say that “chemistry education without laboratory is like painting without colors and canvas or learning how to ride a bike by reading its operating manual” (Tezcan and Bilgin, 2004). “Laboratory method” is one of the learning methods and its main function is to enable students to prove basic

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scientific facts in lab environment (Demirci, 1993). Laboratory activities, to some extent, eliminate learning discrepancies resulting from individual differences. Because all the equipments, tools and techniques used in the labs during the “learning by doing” process also contributes to individual instruction (Çilenti, 1988). Besides, laboratory method improves students’ implication, critical thinking, scientific view and problem solving abilities (Aydoğdu, 1991; Odubunni and Balagun 1991; Serin, 2002). However, it is known that laboratory applications which are very important in chemistry lessons do not get enough attention (Saka, 2002). Teachers may avoid using laboratories because of some different reasons like insufficiencies in traditional verification method, safety doubts of teachers in some risky experiments, some teachers’ lack of self-confidence, inadequate effort and time required to perform experiments (Walton, 2002) therefore lab education do not reflect its full potential (Akgün, 1998; Bağcı Kılıç, 2002; Serin, 2002). As a general evaluation It can be said that lab applications are very important for chemistry education but because of some reasons they are not used efficiently. In Turkey, chemistry curriculum of year 2007 is revised in order to satisfy the mentioned deficiencies (Balıbey, 2008). The renewed curriculum is based on constructivist learning approach which argues that knowledge can be obtained by individuals’ active interaction and meaning can be formed based upon their experiences (Balıbey, 2008; Baki, 2008). Consistent with this approach need for an alternative laboratory environment or mediums has emerged where students can conduct experiments whenever they require and at the same time where they can feel safe and comfortable when conducting risky experiments, enjoy while performing, see every details of the experimental process and can play an active role. Virtual Laboratories (VLs) are mediums that fulfill those indicated needs (Usal, Albayrak & Usal, 2004). In this context, literature review relevant to the subject was done, available virtual chemistry laboratories that are in accordance with the constructivist approach are examined in order to find out their advantages and disadvantages. VL, which provide instruments for education to be done independent from place and time, carries instruction from closed walls of a classroom to anywhere with a computer and enables applications become more dynamic with simulations (Yang and Heh, 2007). The experiments, traditionally conducted in physical labs, can now be performed on a computer. When conducting an experiment in a virtual environment, students actively participate to the whole process, wait for a while the experiment is ongoing and collaborate with their friends for conclusion. This is the main difference of VLs from traditional simulation applications. (Dede, Salzman & Loftin, 1994). Furthermore with the flexibility provided by VLs abstract concepts of chemistry lessons become concrete, daily life and lesson become integrated and students can progress at their own pace and according to their individual learning necessities (Stieff & Wilensky, 2003). VLs overcome some of the problems faced in traditional laboratory applications It is not always possible to see the results of students’ studies in a real laboratory application especially in inadequate laboratory conditions. VLs master the difficulty of having mistaken results that occur as a result of poor laboratory conditions or misuse of the tools and equipments in the laboratory. Besides VLs also overcome the possible dangers that can be seen in the real laboratory conditions or they create the opportunity of conducting the experiments free of charge which costs a lot if performed in a hands-on lab. With the VLs, students have the opportunity to conduct experiments over and over again until they fully understand and at an time and place convenient for them. With using VLs it is intended that the students are more closely involved and have a say in the learning process than the activities done using blackboard and chalk in traditional classrooms. VLs also improve the interaction among students and between students and the teacher and support discussions. A learning environment with increased interaction and active students enhances attention and motivation (Hounshell & Hill, 1989). Moreover some researchers suggested that conducting experiments in VLs is more effective than doing the same experiments in traditional labs (Svec & Anderson, 1995; McCoy, 1991).

2. Virtual Laboratory Studies in Chemistry Education

In this section, VL applications that are based on constructivist learning approach are summarized in Table 1.

Table 1. Virtual Chemistry Laboratories based on constructivist learning approach

Author, Year	Purpose	Sample	Data Collection Tool	Conclusion
Bakar & Zaman (2007)	To assess the effectiveness of a virtual chemistry lab named Vlab-Chem for chemistry subjects based on constructivist approach.	14 chemistry teacher and their 100 students	2 Achievement Test	It is observed that VL applications increase students' success. Besides teachers and students who uses VLs in the dimensions of planning instruction, learning and teaching through multimedia think that it is helpful.
Limniou et al. (2007)	To research the effects of using virtual chemistry lab. before real chemistry lab applications on students.	88 students selected from chemistry department	Achievement Test	As a result it is found out that VL applications increase students' success and their feeling of competence in lessons. Besides students feel more relax, get less tired and understand the lesson more easily.
Kennepohl (2001)	To examine the effects of real versus VL applications on students.	72 students selected from first-year general chemistry course	Lab. assessment questionnaire & Achievement Test	It is observed that VL applications increase students' success, take less time (sample test VL: 24 real lab:36 minute), but is irrelevant lesson performance. Moreover students in the sample group state that they prefer conducting experiment in VL to real labs and they think that it is easier and more understandable to do experiments with the help of software's.
Romli, Bakar & Shiratuddin (2001),	To determine the effects of VLs developed for chemistry lessons on teachers and students.	170 students selected from college & their teacher	observation & interview	It is stated that VL software's create very effective learning environment, support constructivist approach and students centered education, promise great performance with low cost.
Trindade et al. (2002),	To find out the effectiveness of VL which is developed for teaching the phases of water.	70 university students selected from 1 st class	cognitive performance assessment test, Achievement Test, written ex. & interviews	It is seen that students with high level of spatial skills obtain higher conceptual learning level.
Dalgarno (2004),	To measure the potential contributions of virtual chemistry lab and three dimensional learning environments to spatial Learning.	70 students selected from chemistry department	Experimental tool & equipment recognition test, VL assessment questionnaire, chemistry lab. recognition survey, observation	Despite the fact that they are not as much effective as real labs, VL are quite effective for students getting know the lab environment and lab equipments and tools. The level of effect of virtual chemistry lab varies among students.
Oloruntegbe & Alam (2010)	To analyses scientific virtual learning environments in the dimensions of cognitive learning, skills and attitudes.		Literature	This study says that virtual environments lead to increased performance and higher level of learning; students are satisfied by VL applications and think that they are attractive and enjoyable.
Bilek& Skalická (2010),	To assess the results of using real and VL applications together.	78 students selected from chemistry department	Interview, observation & Working Paper	According to the study, most of the students state that they would rather conduct experiments in hand-on labs and they don't think that VLs are mediums to gain experience.
Tüysüz (2010),	To research the effects of virtual chemistry labs on students' success and attitude.	341 students selected from 9th grade high school students	Achievement Test & observation	It is observed that VL software positively affects the success attitudes, and motivation of the students and it enables the student to recognize the learnt concepts more easily. It is also mentioned that VL is an alternative to a real lab when the experiments cannot be conducted in a real lab for some reasons.
Harrison et al. (2009),	To determine the effects of VL software's on secondary school students.	464 students selected from 26 college	Achievement Test, interview & observation	The students who use virtual chemistry lab software give more correct answers to the questions related to experimental techniques and they tend to use this software in chemistry lesson applications (55%) (89% versus 26%) Students state that thanks to the software they can focus on the experimental process and fully understand the experiment.
Gorghiu et al. (2009),	To determine the effects of VL software's in teaching the subjects of "acid-base and neutral solutions "on students.	7th grade students	Observation	It is observed that the content and features of VL software's effect the users' satisfaction and efficiency and enable users to better understand theoretical concepts, and they are also very helpful in hypothesis verification and increase motivation. Besides students take the advantage of the VLs to sharpen their skills in a risk-free, practice environment

Author, Year	Purpose	Sample	Data Collection Tool	Conclusion
Mercer-Chalmers, Goodfellow & Price (2004),	To study effects of virtual chemistry lab software on students' chemistry lab applications.	80 students selected from chemistry department	Achievement Test, interview & observation	With the help of virtual chemistry laboratory software, students do not depend on physical environments for doing experiments and focus on the experimental process rather than equipments & tools can do experiments applications and they feel ready to conduct experiments in a real lab. But it is observed that the effects of VCL differ among students.
Ergül& Binici (2006),	To explore the effects of VL on teaching "gas diffusion and Graham diffusion law"	137 students selected from science education department	Observation & survey	As a conclusion it is said that VL experiments are preferable when there is insufficient experimental equipments and tools or poor laboratory conditions. VL applications can be alternative or supportive to real labs in some cases in graduate or high school level.

3. Conclusion

Literature review showed that VL applications based on constructivist learning approach are majored on secondary school and university level. Results of the studies are summarized as follows:

- It is observed that the affects of VL applications on students are not the same. Some of the VL applications participant students say that those applications are very effective and helpful, whereas some others state that they can not use information technologies effectively and they also think that physical labs are better than VLs because in the VLs there are no sensations like touching or smelling.
- Students who participated in VL applications are better at reporting the experimental process and experiment's result compared to control group students who participate in physical lab applications.
- It is seen that there is very little or no waste of time when doing experiments in VLs compared to conducting the same experiments in physical labs.
- Students doing experiments in VL focus on experimental process, not on the equipments and tools as it is the case for physical labs, and follow the process more closely and at the same time enjoy themselves.
- It is inferred that not all of the students can participate actively to the experimental process in real labs. External effects like insufficient experimental equipment and tools, limited lesson time, safety problems while conducting experiments prevent students from being active. On the other hand only a user friendly software and adequate computer capacity and performance lead to active participation of students in VL applications.
- Some of the other features of VLs that students indicate that they like are being visually more attractive, allowing students to repeat demonstrations that they do not understand or as a review for exams, being cost effective and not wasting any materials, being safe in the operation of instruments and being more technological.

4. Suggestions

Virtual laboratory software's can be used as a supportive tool in real labs or as an alternative lab where there is not an available physical lab. or conditions of the physical lab are insufficient. The most mentioned drawback of the VLs by the students is that they cannot feel, smell or touch. But one of the latest innovations named "haptic" that technology bring in education enables user to feel touch sensation. Therefore it would be useful to include "haptic" compatible systems in developing view VL applications. The studies also recommend to insert avatars to the VLs developed based on student's views and to do some experiments by the help of these avatars.

On the other hand, studies are not sufficient to display the impact of VLs in pedagogical dimension so new studies should be done to investigate this dimension. Besides, some abilities and skills that can be gained in hand-on labs like using lab equipments and tools, measuring, adapting real lab experiences to daily life cannot be obtained in VLs. When developing new VL software these advantages of real labs should be taken into consideration.

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